of these mountains, the air which sweeps over them is forced up to a great height, where it is suddenly cooled; its vapor is condensed; heat is accordingly liberated, by which the surrounding air is expanded, and rises above the usual limit of the atmosphere. It thence flows off laterally, leaving a diminished pressure beneath the cloud: that is, the barometer shows a diminished pressure in the neighborhood of the mountain. The mountain thus becomes the centre of a great storm, and the storm may continue stationary for several days, being apparently held in its place by the action of the mountain.

ON THE AURORA BOREALIS AND THE AURORA AUSTRALIS.

By Professor Joseph Lovering, of Harvard University.

The name of *Aurora Borealis* was given by Gassendi to an appearance in the heavens, now familiar, on the exhibition of it September 2, 1621. The phenomenon is called in the Shetland Islands "The Merry Dancers." The Indian thinks it the spirit of his fathers. Gmelen calls Siberia the birthplace of the aurora.

The various features of the aurora, a greater or smaller number of which may be detected in any aurora, are, 1. Auroral twilight. 2. Arches running nearly from east to west. 3. Streamers. 4. Crown around that point of the sky to which a perfectly free magnetized needle points. 5. Waves. 6. Auroral clouds. The late Professor Olmsted, after enumerating these specialities, remarks: "In different exhibitions of the aurora borealis the various forms above enumerated are sometimes seen single, but commonly more or less combined. In the most magnificent examples they are all seen in company. At first, usually at an early hour of the evening, appears the northern *twilight*, as though the sun, after he had set, was rising prematurely in the north. If a large bank of luminous vapor (which is so peculiar in its external properties, and so distinct from watery vapor, as to warrant the denomination of auroral vapor) rests on the northern horizon, we may expect to see the aurora put on, successively, more of its higher forms; — streamers will begin to shoot upwards; a dark, smoky front will cover the auroral vapor, exhibiting here and there changeable and transient white spots, which suddenly swell out, and often as suddenly disappear; then large columns of a clear, silvery lustre will form in the northwest and northeast, simultaneously, which will sometimes meet and span the heavens with an entire arch; suddenly the columns and clouds of auroral vapor will assume a crimson hue; next all the columns and streamers will rush towards a point a little southeast of the zenith, corresponding to the pole of the dipping-needle, and wreathe themselves around it in a splendid coronet, — and finally auroral waves will begin to flow upward from the horizon toward the same point in surprising undulations, which are often continued a great part of the night. Meanwhile the magnetic needle is violently agitated, and deflected from its normal position."*

Mr. Olmsted divides auroras into four classes. A first-class aurora displays corona, arch, brilliant crimson streamers and waves. A second-class aurora unites only two or three of these four most impressive characteristics; a third-rate aurora exhibits only one of them; a fourth-rate aurora, or an ordinary aurora, is distinguished by neither of these more dazzling peculiarities of the grandest displays.

---

* Smith. Contr., VIII. 5.

The distinguishing features of a rich aurora, notwithstanding the ten thousand varieties, can be recognized in the various descriptions they have received from the man of science, the poet, and the superstitious beholder. We have already given the words of science. This is the language of a poet, describing the aurora in Sweden: "And now the Northern Lights begin to burn, faintly at first, like sunbeams playing in the waters of the blue sea. Then a soft, crimson glow tinges the heavens. There is a blush on the cheek of night. The colors come and go, and change from crimson to gold, from gold to crimson. The snow is stained with rosy light. Twofold from the zenith, east and west, flames a fiery sword: and a broad band passes athwart the heavens, like a summer sunset. Soft purple clouds come sailing over the sky, and through their vapory folds the winking stars shine white as silver." *

Next follows the account, by Rev. Thomas Prince, of the Northern Lights *when first seen in England, in* 1716:—

"There seemed to be a great stream of smoky light rising in the northeast, reaching from near the earth, ascending and waving like the light of a great house or bonfire in a dark evening about half a mile off, which we therefore thought it at first to be; but soon altered our minds when we saw it increasing in breadth, length, and brightness, and pushing forwards, retreating and advancing in the shape of a broad-sword, and like the shooting vibrations of a very high blaze, until it extended to the point over our heads. As it increased in bigness, so did it likewise in the swiftness and fury of its motion, and grew by degrees into a bluish, red and fiery color, almost like to that of the flame of brimstone. Both the color and figure continually changed, I know not how, till at length, on a sudden, it brake forth into the appearance of a raging and mighty torrent of bloody waters, that at first looked like the sudden giving way of a dam, and the sea bearing all irresistibly before it. Whereupon all that part of the heavens over us turned of an inconceivably bright rainbow color, and immediately run into an admirable, inexpressible confusion of an infinite variety of motions, that were amazingly quick and terrible to behold.

"I know not how to give you an idea of this part of the appearance; unless you may conceive something of it by the various and most violent motions that are in a great body of waters, when an higher stream happens to descend and impetuously rush into another. Sometimes they ran into circular forms, sometimes into ovals; sometimes the circles and ovals were variously comprest on their sides by their approaching nearer to one another, or the greater interflux of the nameless and unknown matter. Sometimes they ran winding within and hastily pursuing one another in the manner of whirlpools, and sometimes they ran round and crossed like an 8, and in nnmberless other different figures; that something resembled the various quick and confused rambles of flies in the midst of a room, or of spiders on the surface of a pond; or the perplexing contortions and turnings of a great heap of living eels just covered with water in the bottom of a boat; or as the little foldings and ridges at the tops and bottoms of the fingers; or to mention no more comparisons, like the figures it is probable you have seen of *Cartesius's vortices.*

"All this while, the brightness, bloodiness, and fieriness of the colors before mentioned, together with the swiftness of the motions, increased, insomuch as we could hardly trace them with our eyes; till at length almost all the whole heavens appeared as if they were set on a flame, which wrought and glimmered with flashes in a most dreadful and undescribable manner. It seemed to threaten us with an immediate descent and deluge of fire, filled the streets with loud and doleful outcries and lamentations, and frighted a

* Longfellow in N. A Review, XLV. p. 157.

great many people into their houses: and we all began to think whether the Son of God was next to make his glorious and terrible appearance, or the conflagration of the world was now begun. For the elements seemed just as if they were melting with fervent heat, and the ethereal vault to be burning over us like the fierce agitations of the blaze in a furnace, or at the top of a fiery oven; and the glimmering light looked as if it proceeded from a more glorious body behind, that was approaching nearer and about to make its sudden appearance to our eyes.

"While we expected and wondered what would be the next alteration, and dreaded the consequence, all on a sudden the flaming body above us brake into innumerable spears of light, that at first darted every way and across one another; but in a little while they conformed to the same point of motion, and played in a regular and astonishing manner. At first it seemed as if the very frame of the world was a dissolving; but afterwards one would have thought that there was a furious battle of invisible spirits, that the powers and principalities of the air had broke out into a fierce contention, and that, transforming themselves into angels of light, they were converted into seraphic flames and figures that are said to resemble their natures.

"These distinct and various lights were in the shape of swords, and their several bodies did not appear entirely at the same time, but seemed to begin at one end and shoot a prodigious way to a sharp point in a moment like one continued blaze of a flying firebrand. As they continually appeared and streamed, so they continually vanished like the lucid path of a rocket, while others were incessantly making their appearance in different places round about. The motion of them all was now pointed upwards, and reached some a greater and some a lesser extent; but none above more than from about eight or ten degrees of the horizon to about six or eight from the zenith. For the most part they flashed unequally; but sometimes they seemed to begin, shoot and blaze all together, and made the earth almost as light as day. And then their appearance was like a thousand great swords or blazing stars shooting upwards from all sides of the hemisphere, but leaving, where their points ended, a vacant space in the centre of about ten or twelve degrees diameter, and sometimes of a roundish and sometimes of various multangular figures, directly over our heads. For there seemed to be a remarkable part of the heavens above us which they all violently pushed at, but could never enter.

"Thus they continued their exercise for about a quarter of an hour, but decreased by degrees both in number, quickness, and brightness, till they left the heavens as they were before, and indeed all the time of this amazing appearance almost as clear I think as ever I saw them. It was the more unaccountable and wonderful that there was no palpable cloud hung over us, but we saw the stars shining very plainly all the while in the intervals of the spears and in the very places where they were, as soon as ever they vanished; unless when the brightness of the apparition was so excessive as to drown their light."

I shall arrange what I have to say upon the aurora under these different heads. I. Periodicity, geographical extent, and locality of the aurora. II. The effects of the aurora, such as its light, sound, smell, magnetic and electrical properties. III. Its height and real configuration. IV. Its causes.

I. 1. It is said in Holmes's Annuals,* that the aurora was first seen in New England on December 17, 1719. The author refers to Dr. Trumbull's Century Sermon, preached at New Haven on January 1, 1801, in which occurs the following note:† "The aurora borealis, or northern light, is a

* I. p. 523. † Page 5.

new appearance, in the heavens, to this country, peculiar to the eighteenth century. It had been seen in Great Britain, especially in the north of Scotland, for many centuries past, but even in that country it had not appeared for eighty or an hundred years until March 6, 1716. Its first appearance in New England was on the 17th of December, 1719. It appears to have been a great light, and began about eight o'clock in the evening. It filled the country with the greatest alarm imaginable. It was the general opinion that it was the sign of the coming of the Son of man in the heavens, and that the judgment of the great day was about to commence. According to the accounts given by the ancient people who were spectators of it, there was little sleep in New England that night."

An anonymous account of this aurora by an eyewitness, dated December 15th, 1719, has been republished in the Collections of the Massachusetts Historical Society.* The author says in the first paragraph, "And I hope (though I believe I shall differ from some) I shall say nothing that shall be inconsistent either with Divinity or Philosophy." The aurora was seen from 8 o'clock in the evening, until an hour or two of daybreak the next morning. Its appearance at 11 o'clock "was somewhat dreadful: sometimes it looked of a flame, sometimes a blood-red color: and the whole N. E. horizon was very light, and looked as though the moon had been near her rising." The description ends in these words: "Thus I have given you the best account I am able of this meteor; which, though very unusual here, yet in northern countries more frequent, and seems to me to be what our modern philosophers call Aurora Borealis." He adds, after some attempt at an explanation, of less value than his observation, "As to prognostications from it, I utterly abhor and detest them all, and look upon these to be but the effect of ignorance and fancy: for I have not so learned philosophy or divinity, as to be dismayed at the signs of heaven: this would be to act the part of an heathen, not of a Christian philosopher." See Jer. x. 2.

I would suggest, in this connection, whether the following extracts do not indicate the appearance of an aurora in New England at a much earlier date than the one commonly assigned to its first appearance: —

"About midnight three men, coming in a boat to Boston, saw two lights arise out of the water near the north point of the town cove, in form like a man, and went at a small distance to the town, and to the south point, and there vanished away." "The like was seen by many, a week after." In the second case: "A light like the moon arose about the N. E. point in Boston, and met the former at Nottles Island, — and there they closed in one, and then parted, and closed and parted divers times, and so went over the hill in the island and vanished. Sometimes they shot out flames, and sometimes sparkles."† This was on the 11th and 18th of April, 1643.

The reader is, no doubt, surprised to learn that the aurora was observed for the first time, with the possible exceptions just mentioned, in New England in 1719. For the inference is that no good example of it had occurred since the settlement of the country. The people of New England were too much inclined to dwell upon unusual phenomena in the heavens to have overlooked or been silent in regard to so strange a spectacle as an aurora, had they had the opportunity of beholding one. That the aurora had been uncommon in old England during the preceding century appears from the fact that the great astronomer, Dr. Halley, was, as he says, dying to see one, and expected to die without seeing it. At last the opportunity came, on March 17, 1716, when Halley was sixty years old. In his description of it‡ he says: "This was the only one I had as yet seen, and of which I began to

* II. pp. 17–20.
† Winthrop's Hist. of New England, II. pp. 152, 153.
‡ Phil. Trans., XXIX. p. 416.

despair, since it is certain it hath not happened to any remarkable degree in this part of England since I was born." He adds that the like is not recorded in the English annals since 1574, or for 140 years. It was then seen two nights successively, on November 14th and 15th. It was not so uncommon in the reign of Queen Elizabeth. It was seen at London on January 30th, 1560, and on October 7th, 1564. It was seen twice at Brabant, in 1575. In Germany, in 1580, it was seen seven times in the space of twelve months. In 1621 it appeared in France, and was described by Gassendi under the name of Aurora Borealis. Though it was seen, on the last occasion, at Rouen and Paris, and in the northerly part of the horizon, it was not observed in England, so far as Halley knew. Since then, for eighty years, no account of it, at home or abroad, could be found by Halley, although the Philosophical Transactions had been published for half that period. Mairan's very laborious researches, however, have since accumulated 176 recorded appearances in Europe, between 1621 and 1716. But the same researches have collected 1,118 exhibitions for the thirty-five years following 1716, and only 98 for the thirty-five preceding years. Of these appearances, 116 were in a single year (1730), and 100 in another single year (1732). In the year 1699, which belongs to the period of infrequent auroras, there were 40, although for the few years preceding and following they were very rare.

Notwithstanding this infrequency of the aurora in England for a long period prior to 1716, John Huxham observed it at Plymouth in eighty-one instances between 1728 and 1748.* Celsius says that it was also rare in Sweden before 1716, although between 1716 and 1732 there are found 316 observations of it, and 224 independent appearances. Kirch has collected 106 appearances of the aurora at Berlin, between the years 1707 and 1735. Weidler has made a list of 95 appearances at Wittemberg, in Saxony, between 1730 and 1751. Delisle has furnished a record of 233 appearances at St. Petersburg between 1726 and 1737. Zanotti and Beccari have found 52 appearances in Bologna, or other parts of Italy, between the years 1727 and 1751, and 36 more of doubtful cases. Zanotti, in a description of an aurora which was seen in Italy, as well as in England, on December 5, 1737, remarks: "The Aurora Borealis which was formerly a rare phenomenon and almost unknown in this our climate (Italy), is now become very frequent. A great number have been observed for some years past."† In 1737 Thomas Short speaks of the current year as "having been the most irregularly constituted year of any in my time: not one month but what had the weather of all the seasons, and that not by gradual transitions, but by sudden jerks;" and then says: "I shall only add that our northern lights have been much seldomer and fainter both in appearance and motion than formerly: and whether they will dwindle away and vanish wholly for some years, or whether they have had their former periodic returns, is not certain."‡

This periodicity in the occurrence of the aurora, which seems to be indicated by what has gone before, was confirmed by the comprehensive review of the subject which Mairan took in his *Traité Physique et Historique de l'Aurore Boréale*, published by the French Academy, first in 1731, and a second edition in 1754. Mairan was incited to his great labor by the remarkable aurora of October 19, 1726. Mairan has collected 1,441 appearances, as has already been mentioned (2,137 recorded cases, of which some are duplicates), between the year 583 and the year 1751, and he makes out twenty-two unusual epochs of returning frequency in the course of that long interval.

---

* Amer. Journ. of Sci., XXXIII. p. 297. † Phil. Trans., XLI. p. 593.
‡ Ib. pp. 625 – 630.

I will now consider how the observations of the last hundred years bear upon this question of periodicity. Dalton has collected two hundred and twenty-seven appearances of the aurora in Kendall and Keswick, between the years 1787 and 1793, of which only twenty-nine are duplicates.* In Dalton's catalogue† of auroras observed in Great Britain and Ireland between 1793 and 1834, only sixty-five occurred before 1820, and one hundred and twenty between 1820 and 1834. If a comparison were made in regard to the numbers of *brilliant* auroras, the disparity is still more in favor of the latter period. Between 1806 and 1827, a remarkable aurora was observed only nineteen times, and not at all in the years 1807, 1809, 1810, 1811, 1812, 1813, 1815, 1822, 1823, and 1824. In 1817 and 1820 there were *brilliant* or *extensive* auroras. On the other hand, from 1827 to 1834, a much shorter period, the aurora was observed one hundred and eleven times, and thirty-two times in one year (1830). In this latter period eight are designated as *grand*, and many others as *fine*. Singer says, in his Elements of Electricity, published in 1814, that the aurora was then rarely visible in England.‡

This, in fine, is the European history of the aurora for the last three centuries. For ten years in the neighborhood of 1560, it was common. Then an interval of forty years with scarcely any. About 1620 there were several. Then another intermission for eighty years. Next the eighteenth century abounds in them. In 1707 they were seen in Ireland, Copenhagen, and Berlin. In 1708 they were seen in London. In 1710 they were seen in Leeds. In 1716 they were seen in England, and then several times again before 1723, when they were visible even at Bologna. In 1726 there was an aurora which excited Mairan to his great undertaking. In 1736 Maupertuis saw one at Oswer Zornea, which he thus describes: "I saw a phenomenon of this kind that, in the midst of all the wonders to which I was now every day accustomed, excited my admiration. An extensive region towards the south appeared tinged of so lively a red that the constellation Orion seemed to be dyed in blood. This light was for some time fixed: but soon moved, and after having successively assumed all the tints of violet and blue, it formed a dance of which the summit nearly approached the zenith in the southwest. In this country, where there are lights of so many different colors, I never saw but two that were red, and such are always taken for presages of some great misfortune." In 1765 there was another red aurora. Another was seen in France and Pennsylvania in 1769. In 1814 an aurora with a bright arch was seen all over Great Britain. In 1825, 1827, 1828, 1831, 1833, 1835, 1836, 1837, 1839, 1843, 1847, and 1848, there were splendid auroras visible in Europe.§ It has been concluded, therefore, from European observations, that there is a *secular* periodicity to the aurora. "A period of this kind is comprised between 1707 and 1790: it attained its *maximum* about 1752; there was then a series of twenty years during which they were more rare, but from the year 1820 they have again become more common."‖ When, in September, 1827, a bright aurora was witnessed in Paris, it was stated, by Arago, that none had been seen there before for twenty years.

It may be interesting to inquire how the case stands in the western hemisphere. I have mentioned the surprise excited by the aurora of 1719 in New England. After that there are scattered accounts of the aurora during nearly the remainder of the century. Mr. Greenwood,¶ then Hollis Professor of Mathematics and Natural Philosophy at Harvard College, described one which was seen in 1730, at Cambridge. His successor, Professor John Winthrop,** records nine exhibitions of it between 1741 and 1757. Mr. Caleb Gannett has described an aurora, accompanied by the eastern and western

---

* Met. Ob. and Essays, p. 54. † Ib., p. 248. ‡ P. 253.
§ Thompson's Met., p. 350, &c. ‖ Kaemtz's Met., p. 458.
¶ Phil. Trans. Abridg., VI. p. 115. ** Amer. Journ. of Sci., XL. p. 204.

arch, which was seen at Cambridge on March 27, 1781.* Mr. Manasseh Cutler noticed the aurora repeatedly at Ipswich in 1781.† Auroras were seen at Salem, November 17 and 24, 1720, January 1, and October 2, 1728, and an extraordinary one October 22, 1730. On December 29, 1736 (probably), Dr. Holyoke saw an aurora of which he says: "The first aurora borealis I ever saw. The northern sky appeared suffused by a dark blood-red colored vapor, without any variety of different colored rays. I have never seen the like. Northern lights were then a great novelty, and excited great wonder and terror." On August 6, 1768, a bright streak of light extended from the west-northwest to the southeast, almost as bright as a rainbow. On July 19, 1769, there was an aurora of unusual brightness.‡ On April 21, 1750, the aurora was seen as far south as Charleston, S. C. "We had a most extraordinary appearance of the aurora borealis. One half of the sky seemed like a beautiful streaked liquid flame, so terrible to many of the female inhabitants that some of them were thrown into fits." §

It is well known that Dr. Holyoke, of Salem, kept a Meteorological Journal from 1754 to 1828. That part which relates to the weather has already been published in the Memoirs of the American Academy of Arts and Sciences in Boston. I have consulted the manuscript records of Dr. Holyoke, which he presented to the Academy, and have selected from them all the instances he has recorded of auroras observed by him. Unfortunately, the copy which the Academy possesses is not the original, until the year 1786; and, being prepared for a special purpose, does not contain any record of auroral appearances before 1786. But the Academy possesses the original manuscript Journal of Meteorology kept at Cambridge by Professor John Winthrop, from 1742 to 1779; and also that of Professor Edward Wigglesworth, kept at Cambridge from 1782 to 1793; and that of Dr. Enoch Hale, kept at Boston from 1818 to 1848. In all these Journals, except the last, the auroras are noted with great care; and all together cover more than a century, in which only two years are wanting, namely, 1780 and 1781. From this storehouse I have been able to collect 501 recorded examples of auroras, of which only 92 are duplicates, leaving 409 independent auroras, of which 400 have never before appeared in print. Professor Winthrop has recorded 116 exhibitions of the aurora, Professor Wigglesworth 123, and Dr. Holyoke 262. As these observations have been made at two places only a dozen miles apart, they are strictly comparable with each other, and furnish an almost uninterrupted record of the aurora for one hundred years in this immediate vicinity. The result of my discussion of these observations is, that during the thirty-three years from 1793 to 1827 there were only 17 recorded examples of the aurora. For the thirty-three years preceding 1793 there were 336; and in several instances, a single year of the latter epoch furnishes more cases than the whole of the former epoch; and in one year (1789) there are more than twice as many exhibitions of the aurora as in the whole thirty-three years next preceding 1827. Further details will appear in Volume VIII. of the Memoirs of the Academy.

Professor C. Dewey, then of Williams College, observed auroras, in 1818, on May 23 and 28; also from June 6th to 10th, on September 24 and 25, and October 6 and 7. ‖

The examination of Dr. Holyoke's Journal furnishes *positive* testimony in favor of a conclusion which had been adopted already from *negative* evidence; the absence, that is, of any description of remarkable auroras during the present century before 1827, although the Memoirs of the American Academy and the Transactions of the Philosophical Society, and, after 1818, Silliman's

---

* Mem. Amer. Acad., II. p. 136.
† Ib., I. p. 366.
‡ Felt's Hist. of Salem, II. p. 137.
§ Gent. Mag., XX. p. 418, and XXI. p. 39.
‖ Mem. Amer. Acad., IV. p. 391.

Journal, were in existence, and would furnish a proper medium for any such description. Therefore, as Olmsted remarks, "the splendid arch and other striking accompaniments of the aurora of August, 1827, took us by surprise, and were viewed with wonder by nearly all the existing generation of the countries where it was visible."* Mr. Felt says it caused much apprehension lest the end of all things had come. The arch which signalized this aurora had been seen by Dr. Holyoke, who was then ninety-nine years old, only twice before, namely, in 1755 and 1769. The sight of a magnificent aurora was so unusual that in August, 1827, the bells were rung in Salem to call attention to it. On the contrary, for a period of seventeen years succeeding 1831, 780 auroras were visible in the State of New York, of which 10 were of the highest order, and 35 others only a little inferior. In the single year 1840, there were seen 75 auroras. In 1838, there were 42 in all, and 7 of a *high order*. This period of brilliant auroras still continues: there were four in 1847 and in 1848, three in September, 1851, one in February, 1852, two in 1853, and those of August 28 and 29, and of September 2, 1859.

The discussion of the American auroras leads to the same general conclusion as is suggested by the European observations: namely, that there is a *secular* periodicity, consisting of twenty years or more of abundant exhibitions, separated by intervals, equally long or longer, when the phenomenon, if not wholly wanting, is unaccompanied by any of its more striking characteristics. Though there is a general parallelism in the facts collected on the two continents, the correspondence is not probably so exact as to allow us to disregard in this discussion geographical locality altogether.

The question has also been entertained, whether there were indications of a *yearly* and *daily period* in the exhibitions of the aurora. Mairan states that out of the 1,441 appearances of the aurora which he collected between the years 583 and 1751, 972 were in the six months following October 1, and 469 in the remainder of the year. Olmsted states that of the 780 auroras observed during the seventeen years between 1832 and 1848 inclusive, 346 were in the winter half of the year and 434 in the summer half. Out of 386 auroras observed by Professor Winthrop and Dr. Holyoke at Cambridge or Salem between 1742 and 1827, the winter half of the year claims only 174 and the summer half 212.

Mr. Olmsted remarks: "In regard, however, to *intensity*, the balance has always been in favor of autumn, the greatest auroras having been most numerous in September and November, (August, also?) while they have never occurred in June; but in respect to number, the balance between the seasons of late years has been just the opposite of what it was a century ago, the minimum instead of the maximum number having of late occurred during the winter months; and this is the more remarkable, since the greater length of the winter nights would, of itself, lead us to expect a greater number of auroras at this season of the year." And *in a note:* "Great auroras about the middle of November in 1574, 1607, 1835, 1837, 1840, 1841, 1844, and 1848."

In regard to the *diurnal periodicity*, the general fact is observable, that, although grand auroras, as that for example of August 28, 1859, may last through the whole night, generally the aurora dies out before midnight; and even the best displays usually attain their maximum before 10 and 11 o'clock.

2. Next, as to the geographical relations of the aurora. And first, its area of visibility. The aurora of September 12, 1621, was seen in France, Venice, and Syria. The aurora of October 19, 1726, was seen at Moscow, Petersburg, Warsaw, Rome, Naples, Madrid, Lisbon, and perhaps Cadiz.† That of January 5, 1769, was seen in Pennsylvania and France.‡ The arch

---

* Smith. Contr., VIII. p. 6. † Dalton's Meteorology, p. 229. ‡ Kaemtz's Met., p. 456.

of August 28, 1827, was seen in New England and in Scotland. The auroras of 1830 and 1831 were common to Europe and America.* The aurora of November 7, 1835, was seen from Montreal to Mississippi, and from New England to Cincinnati. Those of January 7, 1831, February, 1837, and September 3, 1839, were visible in Europe and America. The splendid aurora of May 27, 1841, was seen at Cambridge, Philadelphia, New Haven, Toronto in Canada, and Greenwich in Great Britain. The aurora of November 17, 1848, was witnessed in Asia, Europe, and America; in Odessa in the east, and San Francisco in the west. Difference of latitude has more effect upon the appearance than difference of longitude. The auroral displays of August and September, 1859, were witnessed in England, Germany, Italy, as well as throughout the central and southern portions of North America. Humboldt remarks: "Many nights may be instanced in which the phenomenon has been simultaneously observed in England and in Pennsylvania, in Rome and in Pekin."†

Another circumstance to be mentioned in connection with the geographical characteristics of the aurora is, that it becomes more frequent as the magnetic latitude increases, and in Iceland, Greenland, Newfoundland, on the shores of the Slave Lake, and in Northern Canada, it is of nightly occurrence at certain seasons of the year. Lottin and his scientific associates observed, in the winter of 1838–39, in Finmark, in 70° north latitude, 151 displays in 201 nights.‡ Scoresby says that in Iceland the aurora may be seen almost every clear night in winter. Franklin had 142 examples of it in six months in the Arctic sea.

As the frequency of the exhibition increases with the proximity of the observer to the *magnetic*, and not to the geographical pole, auroras abound (according to Scoresby, who observed there in 1822) between the parallels of 62° and 70°. It is not seen best in the very highest latitudes. As the longitude of the magnetic pole is about 97 W. from Greenwich, places in America are nearer to it than places in Europe on the same parallel. Accordingly the aurora is less frequently seen in Italy than in parts of the United States in the same latitude. Erman states that the aurora is not common at Tobolsk; he thinks the double magnetic pole affects the position of it.§ The aurora is more frequent in New England than in Great Britain, though the latter is 10° farther north. The greatest number Dalton observed in England in one year was 30, in the year 1830. In Massachusetts there were 56 observed in the same year.‖

3. At the beginning of the seventeenth century, Gassendi gave the name of *Aurora Borealis* to the appearances under consideration, because of the auroral light and the position of the meteor in the northern point of the horizon. Although the lights may begin at the north, they frequently extend round to the east and west and up to the zenith, and, continuing down to the south, inflame the whole firmament. Parry noticed that on one occasion the aurora was more remarkable at the south than at the opposite point of the horizon. Captain John Ross relates that, in 1818, while his ships were moving south from the parallel of 74° to 66°, he observed the aurora to be in the southern parts of the horizon; but when the ship was south of 66° then the aurora appeared in the northerly parts of the horizon. If the aurora borealis culminates at the magnetic pole, we might expect such a transition of the maximum splendor from the southern to the northern point of the horizon as Ross describes.

Corresponding to the *Aurora Borealis* in the northern hemisphere, there is the *Aurora Australis* in the southern hemisphere (*Südlichter* of the Germans). Forster, who accompanied Captain Cook¶ to the South Seas, says

---

* Amer. Journ. Science, XXII. p. 143.
† Cosmos, I. p. 193.
‡ Voyages, &c., p. 543.
§ Travels in Siberia, I. p. 394 and p. 470.
‖ Amer. Journ. Science, XX. p. 272.
¶ Voyage, &c. Preface, lxv.

that no one before Captain Cook and himself had noticed it. They saw it in 1773, when between 58° and 60° of south latitude, on February 18, and again on six other nights between that date and March 16th. In 1745 it was seen off Cape Horn by Ulloa, and described to Mairan in a letter; possibly it was also seen in 1712.* The *Aurora Australis* was seen in 1820 by Simanoff, astronomer to Bellinghausen's expedition. † It was seen repeatedly by Commander James C. Ross ‡ in his Antarctic expedition in the years 1839–43, and also by Captain Charles Wilkes in the United States Exploring Expedition." § The *Aurora Australis* is better seen in the latitude of 68° than farther south. If no account can be found of an aurora australis comparable with the richer examples of aurora borealis, the want may be explained by the fact that observers approach the high latitudes of the southern hemisphere but seldom, and then only in the southern *summer*, the *short nights* of which are unfavorable for any grand display.

The *Aurora Australis* was observed by Dalton in England ‖ and the *Aurora Borealis* has been seen as far south as Mexico and Peru ¶ On January 14, 1831, Lafonde, when in latitude of 45° south, and in the longitude of the centre of New Holland, saw a brilliant aurora in the northern part of the horizon, which he described to Arago.**

II. *Effects of the Aurora.* 1. The brightness of the auroral light may be judged from the fact that it is sometimes seen in the daytime. "Lowenörn, on June 29, 1786, recognized the coruscation of the polar light in bright sunshine." †† Parry saw the great arch of a northern light continue throughout the day. ‡‡ Perhaps the arch seen at noon in England on September 9, 1827, was of the same kind, as an aurora followed it in the evening. §§ Richardson saw, near Bear Lake, the pulsations of the aurora before the end of daylight: during the day he had noticed clouds assuming the form of the auroral arches and columns. Graham, at Aberfoyle, in Perthshire, observed the same thing on February 10, 1799. He says, the coruscations were as instantaneous and as distinctly perceptible as in the night. |||| Ussher, after describing the aurora of May 24, 1788, adds, that on the next day he saw white rays ascend from all points of the horizon to the pole of dip, where they formed a crown similar to that of brilliant nocturnal auroras. ¶¶ Col. Force, in his *Record of Auroral Phenomena* has adduced another example of an aurora seen in the daytime, about 1806. At 11 o'clock, observers were astonished to see the *streaks and flashes* of the aurora borealis, occupying the same place that they had done the night before.***

The observations made very near the magnetic poles do not indicate that the light is more intense or frequent there than at some distance from them. In Hudson's Bay the brightness of the northern lights is equal to that of a full moon, and in Lapland and Sweden they enliven and illuminate the path of the traveller. Kerguelen describes the night as being as brilliant as the day in north lat. 50°. The auroras are in *oriental* magnificence, "the heavens being on fire with flames of red and white light, changing to columns and arches, and at length confounded in a brilliant chaos of cones, pyramids, radii, sheaves, arrows, and globes of fire." On September 3, 1839, the aurora was so brilliant at New Orleans as to call out the firemen with their engines. Mr. Thompson, after describing the blood-colored aurora of March 26, 1847, the light of which was brilliant in London, says: "And such was the vigilance of the metropolitan firemen, that upon this, as on other occasions, they set out to extinguish the aurora." †††

---

* Mairan, p. 441.
† Edin. Journ. Science, I. p. 347.
‡ A Voyage, &c., I. pp. 166, 261, 265, 283, 311; II. 209, 214, 358, 368.
§ I. p. 151, and II. 322, 328, 360.
‖ Phil. Trans., No. 461. Ib., xliv.
¶ Humboldt's Cosmos. I. p. 192.
** Œuvres de Arago. — Notic. Sci., I. p. 609.
†† Humb. Cosmos, I. p. 190.
‡‡ Journ. of a Second Voyage, 1821-3, p. 156.
§§ Journ. R. Inst., 1828, p. 429.
|||| Trans. Soc. Roy. Edin., V.
¶¶ Trans. Irish Acad., II. p. 189.
*** Smith. Contr., VIII. p. 2.
††† Introd. to Met., p. 355.

To ascertain whether the light of the aurora is *direct* or *reflected* light, physicists have resorted to the test of polarization. Although Arago had found slight traces of polarization in an aurora, and Baudriment claimed the same result for the aurora of October 22, 1839, Arago still hesitated to say that the light was reflected, on account of the possibility of foreign light being mixed with it, or the auroral light itself being reflected after it left the aurora.* Biot attempted in vain to find traces of polarization in the light of the aurora seen by him at the Shetland Islands, August 27, 1817.† Brewster stated to the British Association in 1837 that the light of the aurora was not reflected. Henry,‡ in 1839, failed to find any evidence of polarization either with Savart's or Arago's polariscope. Rankine made a more decisive experiment of a positive character. Having failed to get any sign of polarization in the direct rays of the aurora, he next examined the auroral beams when reflected from the surface of water, and found that the light was bright enough to show traces of polarization.§ He used a Nicol's prism.

2. The aurora was first known simply by its light. In 1740, two Swedish observers, Celsius and Hiorter, observed at Upsal that, during the exhibition of the aurora, magnetic needles were agitated in a way not observed when the needles were made of any unmagnetic substance, as copper. Wargentin, in 1750, made a similar observation. Since then the same thing has been noticed by Van Swinden, Bergman, Biot, Gay-Lussac, Hansteen, Dalton, and too many others to be specially mentioned. Back observed, on one occasion, a change of 8° in the declination. These disturbances by the aurora are felt not in the *declination* only, but also in the *dip* and *intensity* of magnetic force. Examples of this association between the aurora and magnetism have been given in the Almanac for 1857, page 84. Dalton says, "I have never observed any considerable fluctuation of the needle in any evening but when there was an *aurora* visible, except once."‖ The large magnetic disturbances observed at Cambridge, U. S., in May and August, 1841, were accompanied with brilliant displays of the aurora.¶

Arago has studied this relation with great assiduity, and discovered, as early as 1819, that the influence of auroras upon the magnetic needle extends to places which their light does not reach; so that an aurora seen in the north of Europe, or even in the Southern Ocean, telegraphs itself *on invisible wires* to Paris. The fact that Foster, at Port Bowen, *living in the very beams of the aurora,* saw no agitation of the magnetic needle, is explained by the general irregularity of magnetism at that place, or by the disturbance being adapted there to act on *dip*, and not on declination.

3. The electrical effects of the auroral flashes are next to be mentioned. These are not of a *statical*, but a *dynamical* kind. The statical electrical state of the air has been examined, and generally nothing unusual has been found at the time of an aurora. However, on November 17, 1848, (during an aurora at Pisa,) Matteucci observed decided signs of statical positive electricity in the air. Cavallo informs us that the aurora did not affect his experiments with the electrical kite, but that Canton frequently collected electricity in a considerable degree, on such occasions, by means of an insulated rod.** But the flashing of the auroral beams produces the same electrical *current induction* in the telegraph wires as is produced by lightning, only more persistently and regularly, on account of the rapid succession of the flashes. This fact was observed in this country on March 19, 1847, also in September, 1851, and in February and April, 1852. The aurora of last August interfered with the telegraphic operators in Canada and New England so seriously as

---

* Œuvres, S. N., I. p. 603.
‡ Amer. Journ. Sci., XXXIX. p. 366.
‖ Met. Essays, p. 73.
** Cavallo on Elec., I. 75 and II. 38.
† Precis. Elemen. de Phys. Exp., II. p. 100.
§ Phil. Mag., IV. p. 452.
¶ Mem. Amer. Acad., II. p. 54.

to delay the transmission of the news by the steamer Indian. "On the wires between Portland and Boston the operators were enabled to hold conversations, and transmit and receive business, on the current induced by the auroral waves, the usual batteries being disconnected from the wires." Between the Cambridge Observatory and Congress Street, Boston, the wire of the Messrs. Bond was traversed by waves of a minute in duration. The effect was observed even in the daytime. The semi-weekly New York Evening Post of September 28, 1859, has the following paragraph: —

"The splendid auroral display of the night of Sunday, August 28th, was witnessed throughout Germany, where also, as well as in other parts of Europe, its peculiar freaks with the electric telegraph were observed. This was particularly the case at Olmutz, Vienna, Oldenburg, Parduwitz, Cracow, and Brussels. The operators at Antwerp were aroused from their slumbers by the ringing of the signal-bells. At Paris, London, and Berlin, communications were interrupted till 1.30 A. M., while the submarine line between Dover and Ostend remained undisturbed. The aurora was also seen at Rome and other parts of Italy."

The telegraphic engineer of the *London and North Western Railway* has commented upon a remarkable effect upon the telegraphic wires by the aurora of November 17, 1848. He says, "A telegraph passing through Watford Tunnel, (1,600 metres in length,) the wires of which extended out 400 metres at one end, and 800 at the other end, was put *hors de combat* for three hours."* He adds that such an action of the aurora is common; that it is sometimes manifested in the daytime when the aurora is not visible. On the same occasion (November, 1848) Matteucci states that the operators at the telegraph office in Pisa were surprised to find the armatures cling to the magnets of the registers on the line from Florence to Pisa; though the apparatus was in good order, no messages could be sent, even when the battery was increased. Occasionally the armature would drop and the pen would strike, but the manipulation was performed by the aurora.†

4. It has long been under discussion whether the aurora was *audible* as well as *visible*. All may not be satisfied with the satirical remark of Humboldt in his *Cosmos:* "Northern lights appear to have become less noisy since their occurrences have been more accurately recorded."‡ Some compare the noise to the rustling of silk stuff; others to the crack of the electric spark; and many to the noise of a roaring fire.

Gmelin, the botanist, describes the splendid exhibitions of aurora he had witnessed in Siberia as follows: "It begins with solitary pillars of light, rising in the north and almost at the same time in the northeast, which, gradually swelling, at last comprehend a large part of the firmament, rush about from place to place with incredible velocity, and finally cover the whole sky up to the zenith, and produce the impression of a vast tent hung in the heavens, and glittering with gold, rubies, and sapphire. A more beautiful spectacle cannot be imagined. But whoever should see such a northern light for the first time could not behold it without terror. So constantly accompanied is it, *as I have been informed by several intelligent persons*, with hissings and cracklings like those of fireworks. The hunters who go in search of the blue fox to the confines of the Frozen Ocean are frequently surprised by the unexpected appearance of this meteor; their dogs are frightened by it to such a degree that they fall to the ground and will not move till the noise has ceased."§ The inhabitants have a phrase to express this particular noise, which translated means, "The raging host is passing." Cavallo, referring to the aurora, says: "Sometimes these coruscations,

---

* Arago, Œuvres, Notic. Sci., I. p. 705.
† Rive, Elec., III. p. 286. Arago, N. S., I. 702.
‡ Cosmos, I. p. 194. § Voyage en Siberie, II. p. 31. Reise durch Siberien, III. p. 135.

when strong, are accompanied with a sort of crackling noise distinctly, as I remember to have heard it more than once."* In the Edinburgh Encyclopædia we read: "When the aurora appears low, a crack is heard like that of the electrical spark. The Greenlanders think that the souls of the dead are beating the air."† Edmonston, in an account of a remarkable aurora which he observed at Unst, on November 1, 1818, states as follows: "I am now in company with two credible persons who, on a voyage from London to the Shetland Islands, were driven by winds to the latitude of 63½°, near the northernmost extremity of the island. While they were in this latitude an aurora borealis appeared; the noise with which it was accompanied was such that the sailors were afraid to remain on deck."

Edmonston said to Biot that he had himself frequently heard the noise, and thought it most like that proceeding from a large fire. Belknap wrote in 1783, from Dover, N. H., to the Philosophical Society in Philadelphia as follows: "Did you ever, in observing the Aurora Borealis, perceive a sound? I own I once looked on the idea as frivolous and chimerical, having heard it at first from persons whose credulity I supposed exceeded their judgment." He adds, that two years before, while *listening* to the flashing of a luminous arch, he thought he "heard a faint rustling noise like the brushing of silk." Last Saturday evening, he adds, I had full auricular demonstration of the reality of this phenomenon.‡

Murray says: we "can remember, in our boyish days, to have heard this sound most distinctly, while numbers in Scotland can attest the same thing, — a species of fanning sound, like a thin curtain waving in the breeze."§ Ramm, inspector of the forests in Norway, wrote to Hansteen under date of 1825, that, "in the year 1766, 1767, or 1768, he heard the noise of the aurora borealis. Ramm, who was then only ten years old, remarked this effect while traversing a prairie in which there was no forest. The ground was covered with snow and hail. The noise always coincided with the appearance of the luminous jets."‖ Wargentin states that two of his pupils, Dr. Gisler and Hellant, who inhabited for a long time the north of Sweden, related to the Academy of Stockholm that "the matter of the aurora borealis descends so low sometimes as to touch the ground: on the summit of high mountains it produces on the body of the traveller an effect like that of the wind."

Dr. Gisler adds, "that he has frequently heard the noise of the aurora. The noise resembles that of a strong wind, or the noise that some chemical substances make in the act of decomposition." Olmsted states that on one occasion his pupils thought they detected a noise proceeding from an aurora, but he found that they heard the same sound on the next night, when there was no aurora.¶ In 1737, and on several occasions since, it was urged that a *smell* could be perceived in the aurora.**

Besides this positive testimony, we have that of Parrot, Nairne, Abrahamson, Brooke, Dr. Henderson in Iceland, Jameson in Shetland and on the mainland of Scotland, and Hearne at the mouth of the Coppermine River. This sound is said to have been heard in Connecticut in 1781 or 1782,†† and in the fine display of aurora on August 28, 1827, it was mentioned as having been heard in Rochester and Utica, N. Y., and also in New Haven, Conn ‡‡

Muschenbroek reports from the last century that the same fact is generally affirmed by sailors employed in the whale fishery on the coast of Greenland. Biot affirms that among the inhabitants of the Shetland Islands the testimony

---

* Elements of Nat. Phil., III. p. 445. † X. 488. ‡ Trans., II. p. 196.
§ A Treatise on Atmos. Elec., p. 41.
‖ Phil. Mag. for 1826, p. 177. Arago, Notic. Sci., p. 556.
¶ Smith. Contr., VIII. p. 30.
** Amer. Journ. Sci., VIII. p. 392. Arago, N. S., I. p. 558. Phil. Trans., XLI. p. 593.
†† Cited by Thompson. ‡‡ Silliman's Journ., XIV. 101.

was no less full and complete. Sir John Richardson, who accompanied Sir John Franklin to the Polar Seas, relates that the natives of these northern shores, Crees, Copper Indians and Esquimaux, with the older residents in that country, testified that sound was emitted during the display of auroral lights. Hansteen observes: "We have so many certain accounts of the noise attending the polar lights, that the negative experience of southern nations cannot be brought in opposition to our positive knowledge."* And Biot, in view of facts like these, observes: "I am well aware how little reliance is to be placed on common opinion under circumstances calculated to inspire terror, or when influenced by the frightful appearance of rapid and unexpected commotions: but the assertions thus made, like all others, possess a degree of credibility; and if it is unphilosophical to believe without proof, it is equally so to reject without examination;" and again: "If any one will inquire, without bias or prepossession, into the reality of the sounds alleged to proceed from the Aurora Borealis, I am persuaded that he will not hesitate to adopt the common opinion, so striking is the coincidence of testimony on this subject." And still again: "It seems probable, after this mass of testimony, that the meteor sometimes descends so low as to allow us to hear the noise proceeding from it." †

The alleged reality of these auroral sounds has been questioned on the following grounds: Arago quotes Patrin, who passed nine winters in different parts of Siberia, and saw very beautiful auroras without hearing any sound from them. Patrin remarks that, "neither Bishop Eggede, who lived fifteen years in Greenland, of which he has given the natural history and meteorology, nor the pastor Horrebow, who has described 116 auroræ boreales which he observed in Iceland, make any mention of these noises and cracklings." ‡

Lieutenant Hood, who accompanied Franklin to the Arctic regions, observes: "We repeatedly heard a hissing noise, like that of a musket-bullet passing through the air, which seemed to proceed from the aurora, *but Dr. Wentzel assured us* that the noise was occasioned by severe cold succeeding mild weather, and acting upon the surface of the snow previously melted in the sun's rays. The temperature was then —35°, and on the two preceding days it had been above zero." The same sound was heard the next day, when there was no aurora.

Sir John Franklin himself relates that, at Cumberland House in latitude of 54° north, the aurora was displayed almost every evening, but no noise was heard even when it was most active. The residents at the factory, however, assured him that it was frequently attended by a rustling sound. But it is so natural to associate the idea of noise with that of a rapid motion, that observers might easily be carried away by the delusion. Captain Lyon has said: "It is impossible to observe the sudden apparition and the great motion of masses of light such as compose the aurora, without imagining that they are accompanied with a certain rustling: I am convinced, however, that the sound is an illusion. I have frequently remained upon the ice, far from our ships, for hours, with a view of verifying, without having heard anything." §

De la Rive has the following passage: "Necker, who has described a great number of auroras which he observed in 1839–40, in the Isle of Sky, in Scotland, never heard the noise. But he remarks that the noise has been heard very frequently by a person in charge of the meteorological observations at the lighthouse of Swenburghead (at the southern extremity of Shetland). ‖ Siljeström one of the *Commission Scientifique du Nord*, says: "As to the pretended noise, I cannot deny it. But there is reason to suspect an illusion easily explained. In fact, seeing the whole heavens covered with

* See Thompson's Met. † Precis. Element. de Phys. Exper., II.
‡ Bibl. Brit., XLV. p. 89. Arago, Œuvres, Notic. Sci., I. p. 559.
§ Private Journal, p. 100. ‖ Electricité, III. p. 285.

flames, as happens in the finest auroras, and beholding the changeable lights and the rays rapidly darting, it seems to me natural that the spectator (especially if not accustomed to precise observations upon nature) should be led into error, so that in the appearance of fire he should imagine the crackling, and thus refer to the ear what he has discovered by the eye. The illusion, once entertained, would spread rapidly.*

Martins adds: "On returning to France, through Lapland and Sweden, Bravais and myself inquired of all the intelligent persons that we met. To our question, Have you heard the noise of the auroræ boreales? their answer was almost always affirmative; but when we inquired what the nature of this noise was, we obtained the most contradictory replies. When we insisted on the possibility of confounding it with the noise of the wind, that of agitated trees, the rustling of snow swept before the wind, or the murmur of the waves of the sea, we arrived at the conviction that these observers were not on their guard against all such causes of error; these noises struck them in the silence of the night, and because they were concomitant with a brilliant phenomenon, which attracted their attention. Thus these persons themselves were finally led to share in our incredulity, and to confess that they had adopted the received opinion, but that their conviction was not the result of an attentive and faithful observation." †

Biot, though he favored the positive side of this question, nevertheless heard no sounds on occasion of the aurora which he beheld at Unst, in the Shetland Islands, in 1817. He explained the failure by the noise of the sea at the time. Scoresby, Back, Ross, Franklin, Richardson, never heard the noise in the north, nor Thienemann in Iceland,‡ Gieseke in Greenland, Lottin, Bravais, &c., near the North Cape; neither Wrangel and Angin on the Siberian coast of the Polar Sea, though they were familiar with the scenes of greatest auroral display. Wrangel and Gieseke were convinced that the sound they heard was to be ascribed to the contraction of the ice and the crust of the snow, on the sudden cooling of the atmosphere.§

III. The height of the aurora above the earth's surface has been variously estimated. Mairan has given the estimated heights of twenty-three different auroras, seen between the year 1621 and the year 1750. These heights vary from 47 French leagues to 275. The average is 175.‖ Bergman, of Sweden, calculated one seen in 1760 at 334 miles, and another seen in 1764 at 254 miles. Cavendish estimated the height of the auroral arch witnessed in 1784 at from 52 to 71 miles. Dalton¶ computed the height of an aurora in 1793 at 150 miles, and of that of 1826 at 100 miles. Potter calculated the height of one in 1828 at about 200 miles. Dr. Burney, in 1830, found the height between 99 and 134 miles. Airy made the height of two, seen in 1833, 60 and 50 miles. Chevallier has computed the height of an aurora in 1841 and of two others in 1847, at about 160, 175, and 106 miles respectively.** Bravais has worked up the observations collected in 1838–9 by the Scientific Commission of the North, and comes to the conclusion that the auroras there vary in height from about 60 to 100 miles (*between* 100 *and* 200 *kilometres.*) †† Twining calculated the height of an aurora seen in this country in 1835 at about 42 miles; and of two others in 1836 at 100 miles, and 144 miles. ‡‡ Lyman calculated the height of an aurora in 1852 at between 140 and 280 miles. §§

Some doubt has been thrown on these and similar results by the statement of Parry, ‖‖ that on one occasion he observed "a bright ray of the aurora shoot

---

* Voyage, &c., p. 559. † Kaemtz's Met. p. 460. ‡ Edin. Phil. Journ., X. 367.
§ Cosmos, I. p. 195. ‖ Mairan, pp. 433, 434.
¶ Met. Essays, pp. 68, 69. and p. 231. Phil. Trans., 1828.
** Thompson's Met., pp. 360, 361. †† Aurora Borealis, Lottin, &c., p. 542.
‡‡ Amer. Journ. Sci, XXXII. pp. 220, 227. §§ Ib., XV. p. 55.
‖‖ Third Voyage, p. 61.

suddenly downward from the general mass of light, and between us and the land, which was then distant only 3,000 yards." Parry adds: "Had I witnessed this phenomenon by myself, I should have been disposed to receive with caution the evidence even of my own senses, as to this last fact; but the appearance conveying precisely the same idea to three individuals at once, all intently engaged in looking toward the spot, I have no doubt that the ray of light actually passed within that distance of us."

Mr. Hardisty communicated to Capt. Lefroy this fact, in relation to the aurora of 1850: "It appeared between me and the trees on the opposite side of the river, which could not have been 40 feet above the level of the stream, the trees toward the top of the hill being high above it."* An account is given in the American Almanac† of a similar case observed in Vermont. "We had not viewed it long, before we observed the eastern part of it had settled so low as actually to be between us and the highland on the north side of White River, at the distance from us, perhaps, of about one mile and a half. The meteor (aurora borealis) we apprehended must have been nearly perpendicular to White River, and distant about half a mile."

Farquharson, of Scotland, has insisted upon the low elevation of the aurora, assigning it in one case a height of only 5693 feet.‡ Liais computed the height of an aurora seen at Cherbourg in 1853 at about $2\frac{1}{2}$ miles.§ Hood and Richardson concluded, from a comparison of their observations, that the aurora was not more than six miles high. Thienemann, Wrangel, and Struve also assign to the aurora an inconsiderable elevation.‖

To reconcile results so widely at variance with each other, some suppose that the height of the aurora varies very much at different places or at different times. Dalton has criticised the statements of Farquharson and Parry, as inconsistent or insufficient. Humboldt, Forbes, and Thompson think the strange fact mentioned by Parry was an optical deception, explained by the *persistency of sensation in the eye* after the object is removed, as in the case of lightning flashes or fire-balls. Bravais remarks: "The aurora may give so strong an illumination to light clouds that these clouds may seem to disappear, and the aurora be thought between them and the ground. Also the rays may appear to extend down in front of a mountain, but the prolongation is caused by the reflection by the snow."¶

It is generally conceded, however, that the usual method of computing the height of inaccessible objects, namely, by the parallactic angle between the two directions in which two different observers see the same objects, is exposed to great difficulties in its special application to the aurora. The rule is worth nothing, unless the two observers can be sure that they are looking at the same objective reality, and at the same moment. Many of the phases of the aurora are effects of *celestial perspective*. As each observer has his own perspective, this picturesque part of the exhibition is not adapted for determining parallax; and hence distance. In regard to *objective realities*, they are so changeable and complex that there is difficulty in establishing the identity of any particular feature. Possibly the whole phenomenon may be *subjective* instead of *objective*. In this case, every observer has an aurora all to himself, as every man sees his own rainbow, and no one another's. This supposition would preclude all determination of parallax. Arago maintained this opinion, he says, many years ago, in his "Lessons on the Physics of the Globe," given to the Polytechnic School. He does not claim it as original with him, having found, in Memoirs 100 years old,** the idea advanced that

---

* Lefroy's Second Report, p. 14.
† For 1832, p. 109.
‡ Phil. Trans. for 1829, p. 103.
§ Compt. Rend.
‖ Kaemtz, p. 459.
¶ Aurora Borealis, Lottin, p. 531.
** Perhaps he refers to Halley, who says, in 1716: "Hence also it will be easily under-

the aurora of one place is not the aurora of another place. Some have supposed that although the crown of the aurora could not be used for parallax, because it was a *perspective phenomenon*, the eastern and western bow might. On this subject Arago remarks: "*L'orientation magnetique* of the arc of the aurora proves nothing except that the exhibition is arranged symmetrically in regard to the magnetic axis of the earth. As to the *kind* of displacement which the centre of the *cupola* undergoes with the change in the observer's position, it cannot be explained by any *play of parallaxes*. This displacement is such, that an observer who goes from Paris towards the north magnetic pole sees the centre of the cupola, which is to the south of his zenith, rise higher and higher above the horizon. Now this is precisely the opposite to what would occur if the cupola was a radiating summit, and not a simple effect of perspective."* He adds, "As soon as it is established that one part of the appearance is a pure illusion, we do not see why we should suppose that the luminous *bow* of Paris is the same as that seen at Strasbourg," &c.

It has been noticed that the breadth of the same bow is greater at its highest point than at its feet. Bravais computed from this difference the height of the aurora, according to a method of Hansteen, and found it about 60 miles.† The method of Liais, which he practised in the case of the aurora of October 31, 1853, consists in measuring the different times which the arc of the aurora requires to run over the same angle, first near the horizon, and then near the zenith, on the assumption that the real velocity is constant.‡

IV. The explanations of the aurora have been various. Some may be passed over lightly; such as that of the ex-King of Sweden, who imagined the light was ground out by the friction of the earth on its great axle.§ The *savans* of the 17th century supposed that the beams of the aurora might be exhalations from the solid earth. Halley, whose interest in the subject, and late opportunity for witnessing the phenomenon, have already been recited, submitted the following explanation, suggested by Des Cartes's theory of magnetism, and the radiant lines assumed by the iron filings sprinkled around the pole of a magnet: — That a delicate substance issues from the north pole of the earth, which gave the planet its magnetic polarity, and, in certain degrees of intensity or velocity, becomes self-luminous and betrays itself to the eye in the aurora.‖ At a time when the arrangement of the auroral beams in parallelism with the local resultant of the earth's magnetic force, and the action of the auroral flashes upon the direction of a compass-needle, had not yet been noticed, there was a felicity in what Humboldt calls "the bold conjecture hazarded 128 years since by Halley," that the aurora borealis was a magnetic phenomenon. Did not Halley come near anticipating the geometrical conclusions of Cotes and Dalton, when he says: "Nor is it to be doubted but the pyramidal figure of these ascending beams is optical, since according to all likelihood they are parallel-sided, or rather tapering the other way."¶

Cotes, of whom Newton said, "If he had lived we should have known something," was a young contemporary of Halley, and after observing at Cambridge, in England, the aurora of 1620, he gave an exact description of it, which he accompanied with some generalizations upon the subject, of great value geometrically, though no improvement upon the physical view of Halley. Vapors, fermentation, winds, furnish the materials and the motion of the aurora. To Cotes belongs the great merit of seeing, with a geometrical eye, the actual framework of the machinery, and deducing its whole complicated

---

stood that this *corona* was not one and the same in all places, but was different in every differing horizon: exactly after the same manner as the rainbow seen in the same cloud is not the same bow, but different, to every several eye." — Phil. Trans., XXIX. p. 425.

* Œuvres, Notic. Sci., I. p. 554.
† Aurora Borealis, par Lottin, &c., pp. 480, 481.
‡ Compt. Rend., XXXIII. p. 302.
§ Amer. Journ. Sci., V. p. 178.
‖ Phil. Trans., XXIX. p. 422.
¶ Phil. Trans., XXIX. p. 425.

perspective from the foreshortening and projections of parallel columns upon the spherical background of the spectator's firmament.* Contemporary writers missed of the happy physical hint of Halley and the geometrical clearness of Cotes. They contrived mixtures of nitre and sulphur, which exhaled vapors of gunpowder. These, ascending high in the atmosphere, were inflamed by pressure or motion, causing the cloud, light, sound, and motions which characterize the exhibition.†

When Mairan published, in 1733,‡ the great work on the aurora, to which allusion has already been made, he discarded all the theories which had been broached, and advanced a cosmical theory of the aurora, elaborated with great care, and supported with an immense array of circumstantial evidence. The sphere of attraction of the earth, within which it exercises undisputed sway, extending to 186,000 miles, Mairan supposed that the zodiacal light, which in his view is the sun's atmosphere, is entered sometimes by the earth in its revolution round the sun, and that parts of it, becoming entangled in the earth's atmosphere, go to compose the aurora. This was not a lazy conjecture, but an hypothesis carefully examined and cross-examined from manifold points of view, in the defence and illustration of which the great height and the annual and secular periodicities of the aurora were turned to the best advantage.

We have seen when and why the aurora was associated with magnetism. It was also, in the latter half of the same century, associated with electricity. Dr. Priestley says: "That the Aurora Borealis is an electrical phenomenon, was, I believe, never disputed from the time that lightning was proved to be one."§ Cavallo also says: "The aurora borealis, or northern light, was soon attributed to electricity, on observing that by this that flaming light may be imitated, and that the aurora borealis, when very strong, has been known to disturb the magnetic needle, which is also an effect of electricity."‖

In 1779 (?) Franklin wrote this in a paper on the Aurora Borealis: "May not, then, the great quantity of electricity brought into the polar region, by the clouds, which are condensed there, and fall in snow, — which electricity would enter the earth, but cannot penetrate the ice, — may it not, I say, (*as a bottle overcharged*), break that low atmosphere, and run along in the vacuum over the air towards the equator, diverging as the degrees of longitude enlarge, strongly visible where densest, and becoming less visible as it more diverges; till it finds a passage to the earth in more temperate climates, or is mingled with the upper air? If such an operation of nature were really performed, would it not give all the appearances of an aurora borealis."¶ Mr. Rowell has recently attempted an explanation of the aurora, which is no improvement upon this of Franklin.**

Thienemann, who resided in Iceland in 1820, refers the aurora to electrical discharges in feathery clouds in regions where thunder is unknown. Singer expresses thus the association of the aurora with electricity: "When electricity passes through rarefied air, it exhibits a diffused luminous stream, which has all the characteristic appearances of the northern lights. There is the same variety of color and intensity, the same undulating motion and occasional coruscations; the streams exhibit the same diversity of character, at one moment minutely divided in ramifications and at another beaming forth in one body of light, or passing in distinct broad flashes; and when the rarefaction is considerable, various parts of the stream assume that peculiar

---

* Phil. Trans., No. 365. Abridged, VI. p. 83.
† Phil. Trans., No. 395. Abridged, VI. p. 94.
‡ Mairan, Traité Physique et Historique, pp. 4, &c.
§ Hist. of Electr., p. 376.
‖ Sparks's Edition, VI. p. 420.
¶ Cavallo on Elec., I. 75.
** Edin. Phil. Journ., XLII. p. 561.

glowing color which occasionally appears in the atmosphere and is regarded by the uninformed observer with astonishment and fear."*

In 1773, Dalton, after a careful study for six years of the appearances presented by auroras, published a theory which he supposed to be entirely original. He was no reader, and was not aware of the geometrical generalization of Cotes, though attention had recently been called to it by Cavendish,† or of the physical theory of Halley, which, crude as it was, nevertheless associated the aurora with magnetism. He, therefore, reasoned out *originally*, and by the laws of optics, the same conclusions as Cotes had published long before, namely, that the real beams were parallel, and that convergence of rays, crown, and bow were all the wonderful effects of celestial perspective. With such clear notions of geometrical optics, he was prepared to study the aurora of October 13, 1792, which first suggested to him (and, as he supposed, to any one) the relation between the aurora and magnetism. He says: "When the theodolite was adjusted without doors and the needle at rest, it was next to impossible not to notice the exactitude with which the needle pointed to the middle of the northern concentric arches; soon after, the grand dome being formed, it was divided so evidently into two similar parts, by the plane of the magnetic meridian, that the circumstances seemed extremely improbable to be fortuitous; and a line drawn to the vertex of the dome, being in direction of the *dipping-needle*, it followed, from what had been done before, *that the luminous beams at that time were all parallel to the dipping-needle*."‡ These facts, as well as the disturbance which the aurora had been observed to exert over the compass needle, led Dalton to the conclusion that the beams were guided and held in position, not by *gravity*, but by *terrestrial magnetism*. Before Dalton wrote the *Preface* to his Essays, he had discovered the views which Halley had published, of which he says: "The *light* of the *aurora* he is pretty much at a loss to account for, as electricity was then but imperfectly known."§ We may infer from this casual remark to what origin Dalton would look himself, for the *luminosity* of the auroral lines. In the appendix to the second edition of the Essays, published in 1834, he says expressly: "In fact, the light of the aurora exactly corresponds with that of the electric spark, when sent through a tube in which the air has been rarefied to as high a degree as can be effected by a good air-pump."‖

Two other questions now arise. 1. What *are* the auroral lines, to be influenced as they are by the earth's magnetism? and 2. Whence the electricity which runs over and illuminates them? This is, in substance, Biot's answer.¶ The atmosphere is filled, at times, with metallic (Dalton says, ferruginous) particles, highly pulverized. These particles are magnetized by the earth, and then arranged, like so many floating needles, in parallelism with the local resultant of the earth's magnetic forces. These files of needles make a favorable channel for the discharge of electricity between the higher and lower strata of the atmosphere. For these strata are known, by the kite experiment and otherwise, to be unequally charged with electricity.

As the columns of needles are broken, the passage of the electricity through them will be marked by light. In high magnetic latitudes the columns are nearly vertical, and connect strata of unequal elevation and intensity of charge. Near the magnetic equator the lines of needles will lie horizontal and wholly in the same stratum, and hence offer no facility for the electric discharge.

The theory of De La Rive, though based upon the laws of electricity and magnetism as well as the one which has just passed under consideration, combines these laws in a different way to reach the result. He says: "We

---

* Elements of Elec., p. 251.
† Phil. Trans., 1790, p. 103.
‡ Dalton, Met. Essays, p. 148.
§ Ib. Preface.
‖ P. 244.
¶ Précis Element. &c. Physique, II. p. 107, &c.

have seen that the atmosphere is constantly charged with positive electricity, furnished by the vapors which rise from the ocean, particularly within the tropics, and that the earth is left in a negative state of electricity. The recombination and neutralization of these separated electricities is effected through the instrumentality of the moisture diffused between the extreme layers of air or between the upper layer and the earth itself. But it is especially in the polar regions, where the eternal ice prevails, and where the aqueous vapors will be promptly condensed, that the electrical recomposition will take place. The heavily charged equatorial current, originally at a high elevation, approaches the surface of the earth as it approaches the pole. *There* must be the great centre of the electrical discharge, with the accompaniment of light when the charge is intense; if, as is always the case near the poles, and sometimes in the higher parts of the atmosphere, it meets in its path with the minute frozen particles which form fogs and very elevated clouds."* De La Rive adduces, in confirmation of his views, the experience of Bixio and Barral, who, ascending to a great height in a balloon through a serene and cloudless sky, found themselves suddenly in the midst of a transparent veil of small frozen needles, so minute as to be hardly visible. De La Rive goes on to say, that these columns of frozen particles, when employed as the carriers of electricity between the earth and clouds, must be acted upon by the magnetic poles of the earth in the same way as a powerful magnet (an electro-magnet, for example) acts upon a jet of artificial electricity directed upon its extremity. In this experiment, the electricity does not descend indiscriminately upon the end, but comes only to its circumference and forms a luminous ring about it. Moreover, the ring rotates in its own plane round the pole of the magnet. Bravais noticed a rotation of the auroral arch in the direction of west, south, and east. The absolute diameter of the ring must be greater as the distance of the magnetic pole from the surface of the earth *downward* increases. Only observers on the same magnetic meridian would have the same identical summit to their arch. De La Rive is at no loss to account for the noise and the smell which are said sometimes to attend upon the aurora, according to the analogy which he thinks to establish between the great case of nature and the artificial, experimental illustration. The lunar halos which often precede the aurora, and the fall of rain or snow in the high latitudes which precedes or follows the aurora, all these alleged facts De La Rive considers as favorable to his hypothesis.

The late Professor D. Olmsted of Yale College, who published, in 1856, a valuable contribution* on the "Recent Secular Period of the Aurora Borealis," favors the theory of Mairan to the extent of supposing the aurora to have a cosmical origin. He argues against the *telluric* origin and for the *cosmical* origin of the aurora: 1. Because of the great extent of country over which the same aurora is displayed. 2. Because the principal phases occur on *all meridians*, not at the same *absolute* instant, but at the same *local times*. 3. On account of the great velocity of the motions. 4. On account of the periodicity of the aurora, especially the secular period. Therefore the material of the aurora is foreign to the earth, being the zodiacal light, as Mairan supposed, or some other nebulous patch which the earth encounters in its motion round the sun. As the aurora is susceptible to the earth's magnetism, this matter is magnetic certainly, and perhaps ferruginous. It may be illuminated by electricity or by the friction of grinding against the earth's atmosphere. Its own motion and those of the earth are so accommodated to each other, that at one period the earth almost escapes it, at another period barely grazes it, and at still a third period cuts directly into this nebulous substance. Mr. Olmsted observes: "The occurrence of these exhibitions at certain hours of the night, that is, the *diurnal* periodicity, (a circum-

* Elec., III. p. 288.

* Smith. Contr., VIII.

stance which belongs to auroras of the polar regions, when it is continual night, as well as to lower latitudes,) plainly indicates that the phenomenon has *some* relation to the position of the sun, although, after much reflection, I have not been able to satisfy myself as to the precise nature of that relation. The most promising chance of solution of the case, which has suggested itself to my mind, is that which connects it with the zodiacal light, which is known to maintain a nearly constant position with respect to the sun."* As early as 1837, Mr. Olmsted published his opinion that the origin of the aurora "is to be sought for in a source extrinsic to the earth."† He does not think that the recent theory of Rev. George Jones, namely, that the zodiacal light is a ring around the earth, and not around the sun, will diminish its availability for supplying the auroral material.

Mr. Olmsted quotes the following passage from Humboldt, to show that the latter treated the cosmical origin of the aurora with some favor. "If we regard falling stars and meteoric stones as planetary asteroids, we may be allowed to conjecture that, in the streams of the so-called November phenomena, when, as in 1799, 1833, and 1834, myriads of falling stars traversed the vault of heaven, and the *northern lights* were simultaneously observed, our atmosphere may have received from the regions of space some elements foreign to it which were capable of exciting electro-magnetic processes.‡

Whatever may be the origin of the material which composes the auroral beams, it is, during the time of action, so far within the earth's atmosphere as to be subject to the earth's rotation. Biot found, in September, 1817, that the aurora did not move to the west with the stars, but maintained the same position in the visible firmament. Bravais also concludes his discussion of the aurora as follows: "It seems to me to be the result of our observations, that the aurora borealis has its seat at heights generally more than 100,000 metres, near the limits of the atmosphere, and that it must be considered amenable to its general movements of rotation and translation. But it is impossible at present to declare the *nature* of the *matter* which generates it. The analogies which ally the aurora borealis to terrestrial magnetism, those which seem to associate it with the *cirrus cloud* of high regions of the air, and also to the shooting stars, may put us upon the track of new observations, but they are not sufficient to close this important problem."§

I would remark, in conclusion, that there is not, necessarily, any inconsistency in the terrestrial and cosmical theories. The *matter* may come from the zodiacal light. But after the earth has obtained possession of it, it may *arrange* and *illuminate* it in accordance with the laws of magnetism and electricity, as applied to the case by Dalton and Biot.

When Mairan resolved the aurora into the zodiacal light, he left its light to be explained as that of the zodiacal light itself may be: in any way possible. He also supposed that the tails of comets were streamers of the zodiacal light in which these strange bodies had arrayed themselves. Euler,‖ on the contrary, thought to explain the zodiacal light, the aurora borealis, and the tails of comets, all upon one principle: the *impulse* of the sun's rays. This impulse, acting on the sun's atmosphere, repelled some of it in a zodiacal ring; acting upon the comet's atmosphere forced some of it to form a tail; and acting upon the earth's atmosphere carried it high enough above the earth to be outside of its shadow, and to be in sunshine even at night.

Sir William Herschel, in his remarkable paper on the solar spots, published in 1801,¶ has thrown out the suggestion, that the same causes which, in intense activity, produce the light of the sun, operating on the earth upon a diminutive scale excite the light of the aurora. His language is, "But it

---

* Smith. Contr., VIII. pp. 50 - 51.
† Amer. Journ. Sci., VII. pp. 127 - 293.
‡ Cosmos, III. p. 50.
§ Aurora Boréales, par Lottin, Bravais, &c., p. 550.
‖ Acad. Berlin. 1746.
¶ Phil. Trans., XCI. p. 304.

should be remembered that, on account of the great compression, arising from the force of gravity, all the elastic solar gases must be much condensed; and that, consequently, phenomena in the sun's atmosphere, which in ours would be mere transitory coruscations, such as those of the *aurora borealis*, will be so compressed as to become much more efficacious and permanent." If the analogy here suggested is a real one, it cannot be said whether our knowledge of the origin of the aurora or of the sun's light will be the greater gainer by it.

Captain John Ross, in the Appendix to the account of his second voyage, published in 1833, attributes the aurora to the sun's rays reflected from the ice and snow round the poles. The effect on the magnetic needle he attributes to the heat of these rays, as the same effect, in his opinion, was produced when the rays of an artificial flame were condensed upon it Mr. Wharton had the same view as Ross, because the aurora came from a place in the same azimuth as the sun, and converged to the opposite point above. Ross derives the color of the aurora from the brilliant colors of the ice. In the southern hemisphere, the ice is not colored, (according to the statement of Captain Cook,) and the aurora is white.

METEOROLOGICAL INFORMATION.

I. METEOROLOGICAL TABLES FOR PORTLAND, Me.

For the Year ending December 31st, 1858. By Henry Willis.

Lat. 43° 39′ 24″.49 *N.*, *Long.* 70° 15′ 24″ *W.*

1. Barometer.

Barometer cistern with constant level, No. 1225, by J. Green, N. Y. Scale, English inches, reduced to 32° Fahr. Station 87.5 feet above the mean level of the sea.

Months.	Highest.					Lowest.					Monthly Mean for each Hour.			Mean for the Month.
	Day.	7 A. M.	2 P. M.	9 P. M.	Mean.	Day.	7 A. M.	2 P. M.	9 P. M.	Mean.	7 A. M.	2 P. M.	9 P. M.	
		inch.	inch.	inch.	inch.		inch.	inch.	inch.	inch.	inch.	inch.	inch.	inch.
January,	23	30.73	30 66	30 56	30.65	4	29.55	29.29	29.31	29.38	30.000	29.939	29.952	29.956
February,	1	30.26	30.37	30.37	30.33	10	29.22	29 20	29 41	29 28	29.889	29.819	29.862	29.856
March,	20	30.29	30.16	29.97	30.14	9	28 99	28.97	29.18	29.05	29.754	29.671	29.761	29.721
April,	19	30.24	30.16	30.12	30.17	14	29.43	29.34	29.36	29.38	29.845	29.793	29 827	29.822
May,	3	30.41	30.29	30.25	30.32	24	29.44	29.32	29.55	29.44	29.946	29.912	29.973	29 944
June,	9	30.11	30.04	30.01	30.05	11	29.54	29.66	29.79	29.66	29.915	29 873	29 892	29.897
July,	6	30.25	30 18	30 05	30.16	22	29.62	29.63	29.67	29.64	29 914	29.886	29.892	29 897
August,	13	30.24	30.27	30 28	30.26	29	29.62	29.57	29.59	29.59	29.947	29.900	29.972	29.940
September,	19	30.34	30 33	30 35	30.34	16	29.70	29.75	29.15	29.55	29 994	29.935	29.970	29.967
October,	17	30.55	30.49	30.44	30 49	7	29.81	29.53	29.33	29.56	29 992	29.963	29.955	29 970
November,	2	30.35	30.33	30.38	30.35	24	29 50	29.44	29.47	29.47	29 817	29.777	29.804	29.799
December,	12	30.39	30.45	30.56	30.47	22	29.03	29.27	29.63	29.31	30.014	30.011	30.015	30.010
An. Mean,		30.35	30.31	30.28	30.31		29.45	29.41	29.45	29.44	29.918	29.873	29.907	29.898

Barometer highest, Jan. 23d, at 7 A. M., 30.73 in.; lowest, March 9th, at 2 P. M., 28.97 in.